

- 18 -

We claim:

1. A system for forming a layer on a coating surface of a substrate, comprising:
a reaction chamber configured to enclose the coating surface of the substrate, the
5 reaction chamber including at least one inlet configured to supply at least two
precursors to the coating surface, the precursors being reactive with each other in the
reaction chamber to produce a layer material;
a precursor exposure controller configured to alternately deliver pulses of the
at least two precursors to the coating surface, wherein the layer is formed by reaction of
10 the precursors with accumulation of the layer material on the coating surface;
a monitor configured to measure a characteristic of the coating surface of the
specimen during or after layer formation and to provide a monitor output corresponding
to the measured characteristic; and
a controller connected to the monitor, the controller including a pulse selector
15 configured to select a number of pulses delivered to the coating surface based on the
monitor output.
2. The system of claim 1, wherein the reaction chamber includes a chamber
wall having a perimeter aperture and configured to retain the substrate so that the
20 coating surface faces an interior of the reaction chamber and a second surface of the
substrate faces away from the interior of the chamber.
3. The system of claim 2, further comprising a seal situated at the perimeter
aperture between the substrate the chamber wall, the seal being configured to impede
25 flow of precursors out of the reaction chamber.

- 19 -

4. The system of claim 1, wherein the reaction chamber includes a monitor window situated to avoid exposure of the monitor window to at least one precursor.

5 5. The system of claim 4, further comprising a flow shield configured such that a monitor window situated relative to the flow shield is located substantially outside the flow of a precursor.

6. The system of claim 1, wherein the monitor is configured to measure an optical property of the coating surface.
10

7. The system of claim 6, wherein the optical property is reflectance or transmittance.

8. An apparatus for forming a multilayer optical filter, the apparatus
15 comprising:
a reaction chamber configured to retain a substrate, the reaction chamber defining a monitor aperture;
at least one precursor inlet for admitting at least one precursor to the reaction chamber;
20 at least one exit port for removing the precursor from the reaction chamber;
an optical measurement system comprising a source configured to produce a measurement light flux and to direct the light flux to the monitor-aperture, and a receiver configured to receive a portion of the measurement light flux from the monitor aperture; and
25 a controller in communication with the receiver and configured to select a number of alternating exposures of the substrate to at least one reactant based on a measurement of the measurement light flux returned to the receiver.

- 20 -

9. The apparatus of claim 8, wherein the source is a laser.

10. The apparatus of claim 8, wherein the receiver includes an optical spectrum
5 analyzer.

11. The apparatus of claim 8, further comprising a planetary system configured
to rotate the substrate in the reaction chamber.

10 12. The apparatus of claim 11, wherein the controller is configured to determine
a rotation rate of the substrate.

13. A reaction chamber for atomic layer epitaxy, comprising:
an exterior wall,;
15 an aperture defined in the exterior wall;
a substrate holder situated at the aperture; and
a seal situated to impede a flow of precursors between the substrate and the
exterior wall.

20 14. A method of forming a layer on a substrate, comprising:
delivering a measurement light flux to a surface of a substrate;
alternately exposing the surface of the substrate to a first precursor and a second
precursor, the first and second precursors being reactive with each other to form a first
material;
25 allowing the first and second precursors to form a sublayer of the first material
on the surface; and

- 21 -

determining a characteristic of the sublayer or of a combination of the sublayer with earlier formed sublayers on the surface, based on a measurement of a portion of the measurement light flux received from the surface.

5 15. The method of claim 14, further comprising the step of exposing the surface of the substrate to a number of alternating exposures, the number being based on a measurement of the portion of the measurement light flux.

10 16. The method of claim 15, wherein the step of determining a characteristic of the sublayer or of a combination of the sublayer with earlier formed sublayers on the surface is based on a measurement of a portion of the measurement light flux received from a portion of the surface distinct from the portion at which the characteristic is determined.

15 17. The method of claim 15, wherein the measurement is a measurement of transmittance or reflectance.

 18. The method of claim 15, wherein the measurement is a measurement of transmittance or reflectance as a function of wavelength.

20

 19. The method of claim 15, wherein the measurement is an ellipsometric measurement.

 20. A computer-readable medium containing computer-executable instructions
25 for selecting a number of sublayers formed in atomic layer deposition based on a measurement of a substrate.

- 22 -

21. A wavelength-division filter, comprising a plurality of alternating layers of high-index and low-index materials, wherein at least one of the layers includes a number of sublayers selected based on a measurement light flux transmitted by or reflected from the filter.

5

22. The wavelength-division filter of claim 21, wherein the sublayer consists essentially of a combination of a first precursor and a second precursor.

23. An optical filter, comprising:

10

a substrate;

a plurality of sublayers that combine to form at least one layer on the substrate, the sublayers produced by an alternating exposure of the substrate to two or more precursors, wherein a number of the sublayers is selected based on a measurement of an optical property associated with the layer or one or more of the sublayers.

15

24. The optical filter of claim 23, wherein the sublayers are configured to produce a spectral transmittance based on a gain spectrum of an optical amplifier.

25. The optical filter of claim 23, wherein the filter has a spectral transmittance or reflectance having a spectral bandwidth $\Delta\lambda_1$ of less than about 1.0 nm, wherein $\Delta\lambda_1$ is a full-width of the spectral transmittance or reflectance, respectfully, at 0.5 dB down from a maximum spectral transmittance or reflectance.

20

26. The optical filter of claim 25, wherein the spectral bandwidth is less than about 0.5 nm.

25

- 23 -

27. The optical filter of claim 25, wherein the spectral bandwidth is less than about 0.1 nm.

28. The optical filter of claim 23, wherein at least one layer consists essentially
5 of niobium oxide.

29. An optical filter, comprising:
a substrate; and
alternating layers of a first material having a first refractive index and a second
10 material having a second refractive index, wherein the first material consists essentially
of niobium oxide.

30. The optical filter of claim 29, wherein the second material consists
essentially of aluminum oxide.
15

31. The optical filter of claim 29, wherein the layers of the first material include
at least one sublayer.

32. The optical filter of claim 31, wherein the second material consists
20 essentially of aluminum oxide.

33. An optical layer, comprising a plurality of sublayers of at least two different
sublayer materials, wherein the optical properties of the layer are a function of the
optical properties of the sublayer materials.
25

34. The optical layer of claim 33, wherein the layer has an entrance surface and
an exit surface configured to receive a light flux and emit the received light flux,

- 24 -

respectively, wherein an optical property of the layer changes monotonically along a thickness dimension that is substantially parallel to the entrance surface or the exit surface.

- 5 35. The optical layer of claim 34, wherein the optical property that changes monotonically is refractive index.